Signal Obstructions at GNSS Stations: Benefits From Multi-GNSS Observations

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Introduction

The high accuracy of International GNSS Service (IGS) products requires amongst other things that the location for GNSS antennas is nearly optimal for the observations. This includes a low-multipath environment and little to no signal obstructions. However, this is not guaranteed for every station, especially in urban areas and mountainous regions. As some applications such as GNSS for sea level studies or to monitor landslides, require GNSS antennas to be installed at a specific site, it is clear that the environment might not be favorable for GNSS observations. In this study, we investigate the effect of signal obstructions on station positions, specifically the up component, based on simulated obstruction scenarios using a modified Bernese GNSS Software version 5.2 (BSW52) (Dach et al., 2007). The effects of different obstruction scenarios and the impact of multi-GNSS (GPS+GLONASS for now) observations for both clear and obstructed stations are discussed.

Multi-GNSS observations provide an opportunity of diversity and redundancy through the different signal and orbital characteristics, such as orbit inclination, revolution period and repeat cycle of the different systems. As the signal differences between the systems are not the main concern here, the orbit characteristics of the systems (GPS and GLONASS) is listed in Table 1. The latitude-dependency of the systems is caused by the inclination of the satellites' orbital plane (Santerre, 1991). As the ground track of a satellite repeats for GPS but shifts every day for GLONASS, it makes the latter longitude-independent while the former is somewhat also longitude-dependent (Dach et al, 2009). This can be demonstrated from the skyplot in Figure 1, where stations IRKJ and JOZ2 are separated in longitude by 83 degrees (Figure 2). The latitude-longitude dependency and any other orbit related effects of the systems will respond to specific obstruction scenarios differently. This will be discussed in this poster.

Table 1 Main orbit characteristic differences between GPS and GLONASS

	GPS	GLONASS
Orbital planes	6	3
Satellite per orbital plane	4 to 6	8
Orbital plane inclination	55^0	64.8^0
Ground track repeatability	1 sidereal day	1 sidereal day
Geometry repeatability	1 sidereal day	1/3 sidereal day
Latitude dependency	Yes	Yes
Longitude dependency	Yes	No

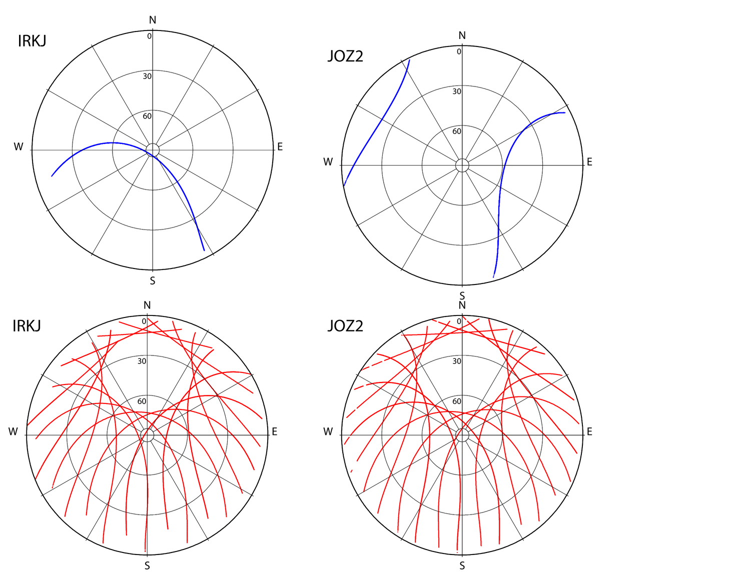


Figure 1 Skyplot of GPS (SV18) (*blue lines*) and GLONASS (SV120) (*red lines*) satellites for stations IRKJ and JOZ2 over 10 days. The stations are nearly on the same latitude but are separated by 83 degrees longitude. The plots show longitude dependency and independency for GPS and GLONASS, respectively

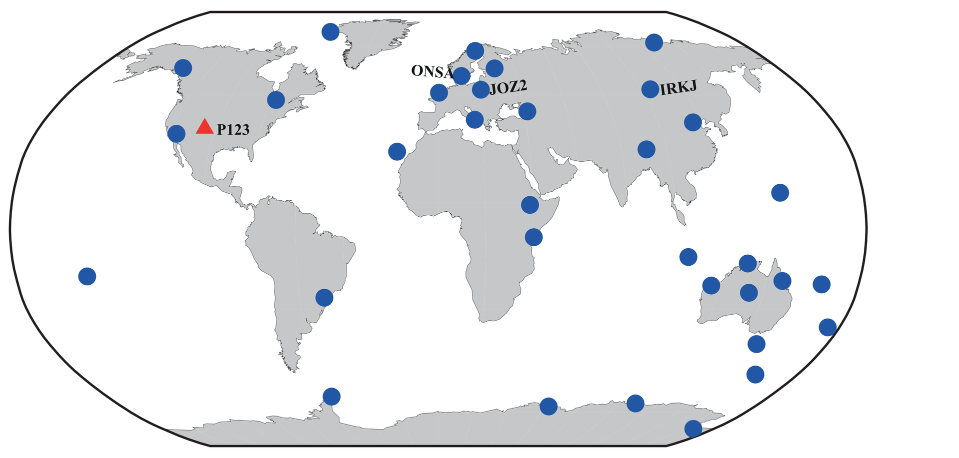


Figure 2 Map of stations used for this study (*blue dots*) and P123 station (*red triangle*). P123 is a severely obstructed site from the UNAVCO/PBO network)

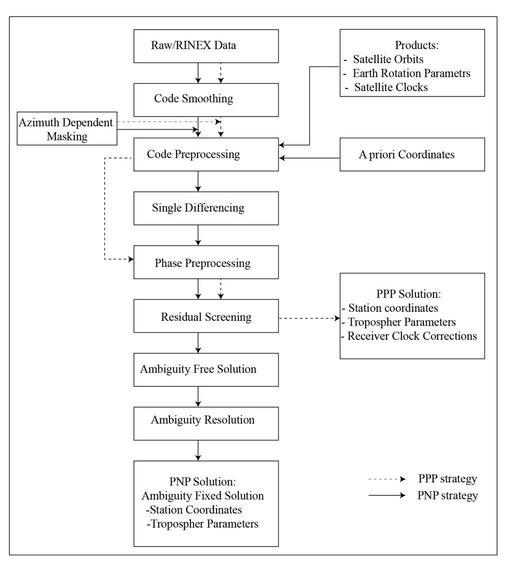
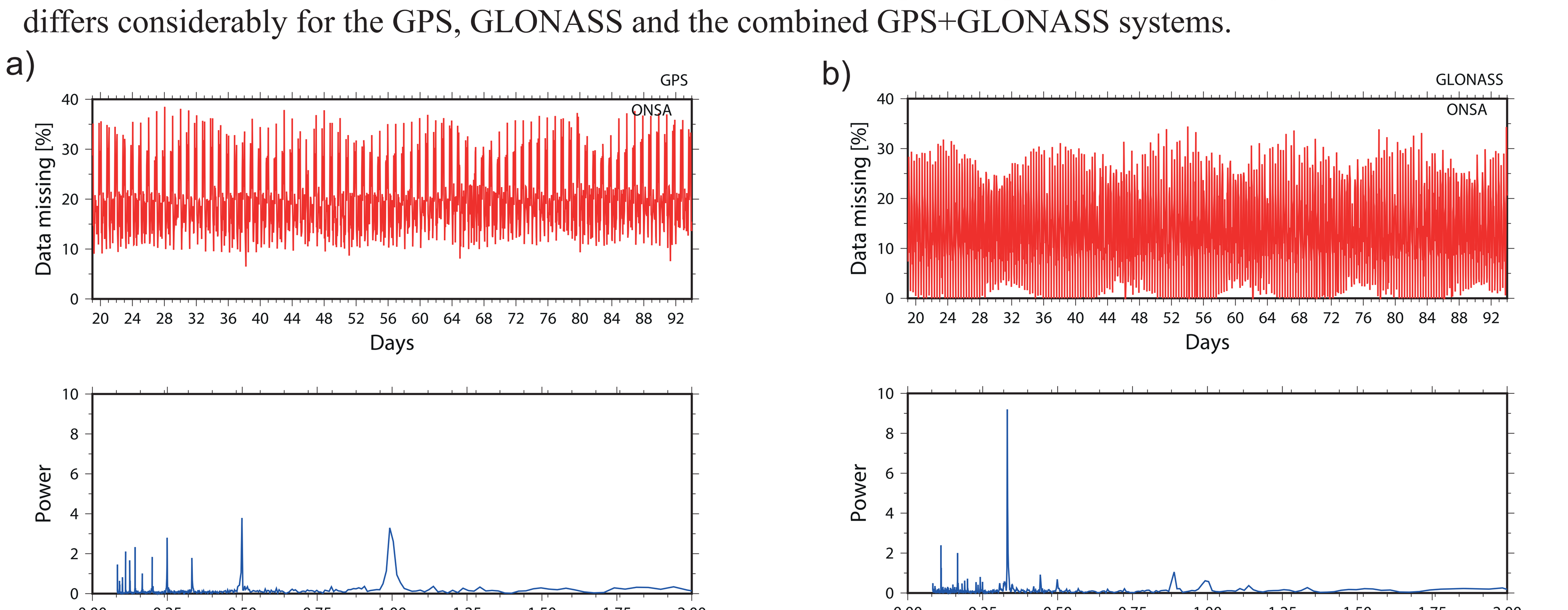


Figure 3 A flow chart of processing steps for simple Precise Point Positioning (PPP) and Precise Network Positioning (PNP) strategies with and without applying obstruction scenario in BSW52

Effects of Obstructions

Figure 4 shows the percentage of missing data and power spectra for station ONSA caused by a simulated obstruction in the east direction (the scenario in Figure 5b). The upper panel of the graphs shows the time series of the missing data from day-of- year (DOY) 019 to 092, 2014. The power spectra of the missing data time series differs considerably for the GPS, GLONASS and the combined GPS+GLONASS systems.



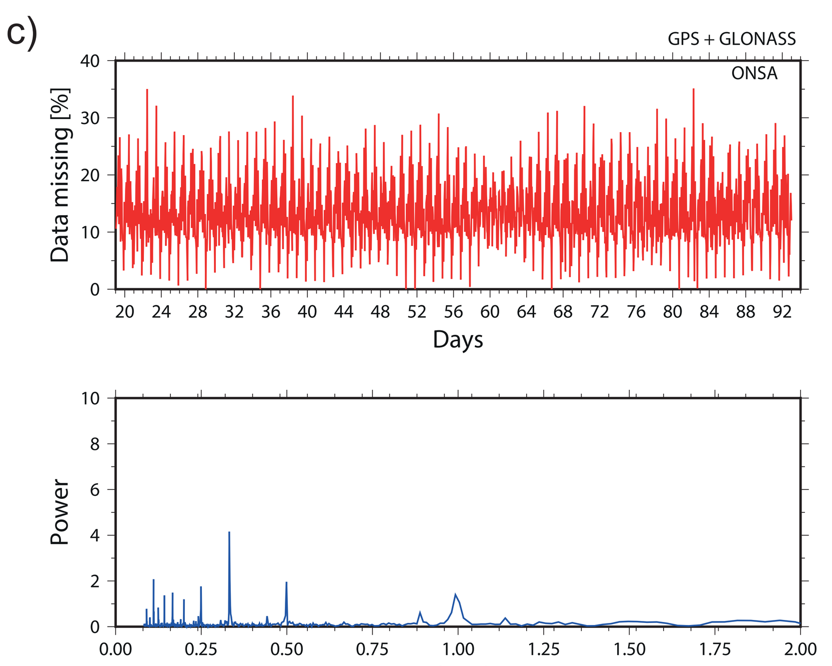


Figure 4 Percentage of missing data for station ONSA (See Figure 2 for map). *Red line* is the time series of Percentage of missing data caused by the obstruction scenario in Figure 5b, *blue line* is the power spectra of the percentage of missing data time series.
a) for GPS only, b) for GLONASS only and
c) for the combination of GPS + GLONASS

- Main features of the percentage of missing data:
  - ► The misssing data time series and the power spectra show periodic signals
  - ► 1 sidereal day and half a sidereal day for GPS
  - ► 1/3 sidereal day for GLONASS
  - ► The combined GPS+GLONASS system has features from both systems but with reduced power.
- The features are corresponding to the repetition of the satellite geometry of the systems (Table 1).
- The features in Figure 4 can be an indication that errors due to obstructions (or multipath) can propagate into long-term position time series with power at the GNSS-specific draconitic periods and its harmonics (Ray et al., 2008, King et al., 2010)

Results: Up Component

- Obstruction scenarios in the North, East, South and West directions are simulated (Figure 5)
- PPP solutions for all scenarios and a reference solution without obstructions are generated using the processing strategy in Figure 3.
- All solutions are created using the same European Space Agency (ESA) satellite orbit and clock, and Earth Orientation parameter (EOP) products. Identical models were employed except for the application of the obstruction scenario, which enables the differences to reflect the effect of the obstructions.
- EOPs, satellite orbits and clocks are fixed while site coordinates, tropospheric parameters and receiver clocks are estimated for each solution.
- The applied obstruction scenarios affect all the aforementioned parameters. However, only the effects on the up component are presented here.
- Daily coordinate differences are computed for all solutions (with obstruction scenario) with respect to the reference solution.

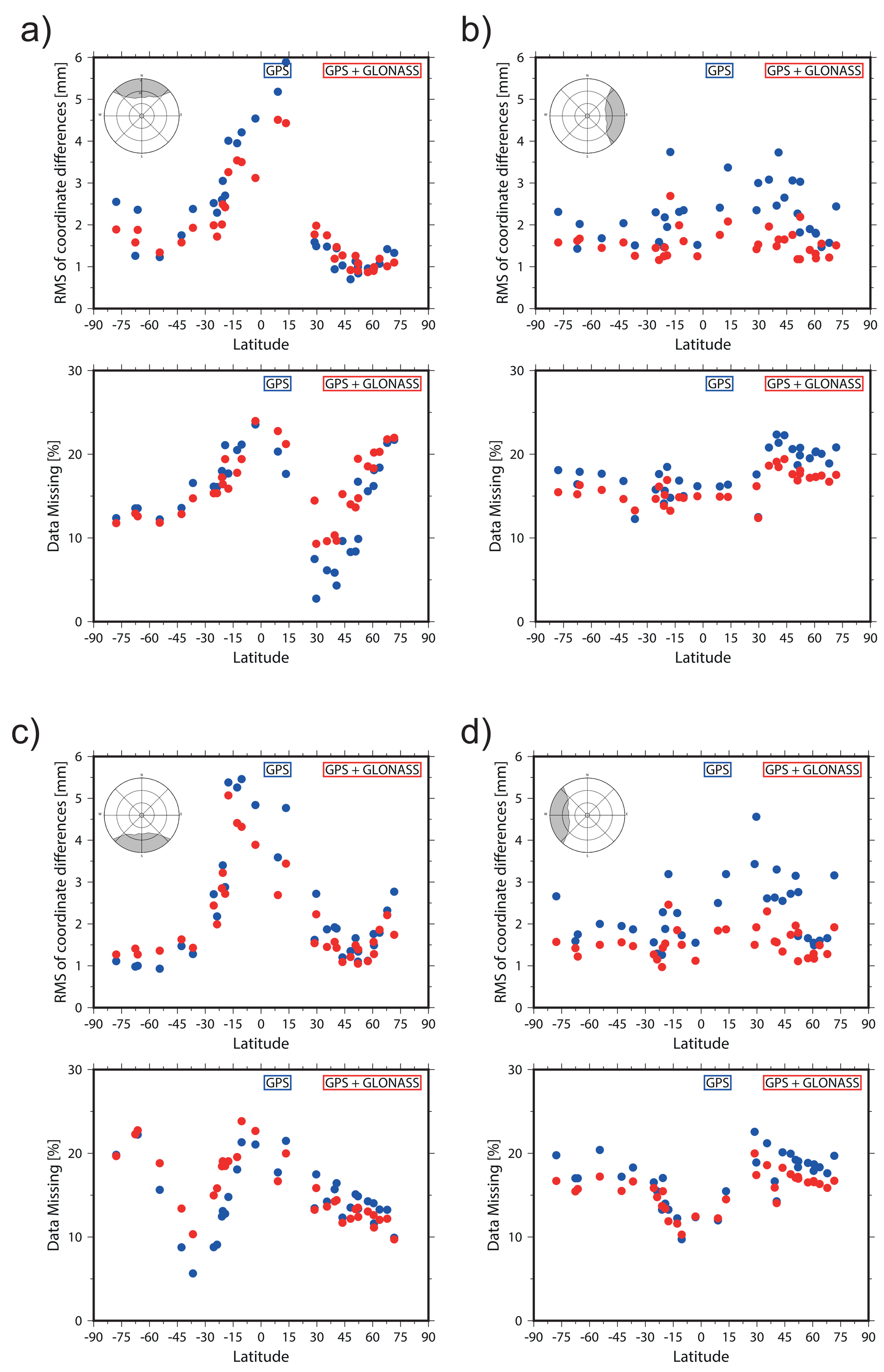


Figure 5 RMS of daily coordinate differences versus station latitude for the up component (upper panel) and percentage of missing data (bottom panel) for all stations in Figure 2. The grey shaded area of the obstruction profile inset is the simulated obstruction scenario and represents a severe case. a) for North, b) for East c) for South and d) for West scenarios. *Blue* and *red* dotes are for GPS-only and GPS+GLONASS solutions.

►Main Results:

- The North and South (Figures 5a and 5c) obstruction scenarios show a clear latitude-dependency
- Stations near the equator are more affected than others from all North-South scenarios
- The North obstruction scenario affects stations on the Southern Hemisphere and the South obstruction scenario affects stations on the Northern Hemisphere
- GLONASS observations are more affected than those of GPS by the North-South obstruction scenarios
- The RMS of the coordinate differences for the up component is lower for the combined GPS+GLONASS solution which shows the contribution of GLONASS to the combined solution

Resuts: Long term effects

- The obstruction profile from the severely obstructed UNAVCO/PBO site P123, Figure 6a, is extracted and used as a scenario for the IGS sites. Figures 6b and 6c show the skyplots for ONSA before and after the P123 obstruction scenario is applied, respectively. A PPP solution (Figure 3) is created from 2011-2015 to investigate the long term effects of the scenario.

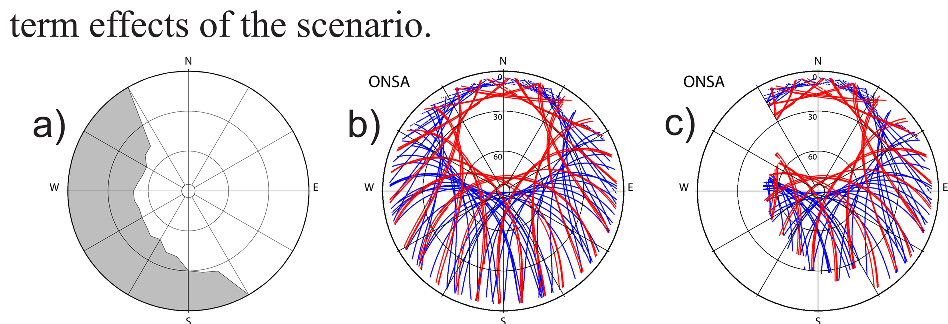


Figure 6 a) The obstruction profile extracted from P123 (*grey colour* is the obstructed part of the sky) b) the actual skyplot for ONSA without obstructions c) the skyplot with the P123 obstruction scenario applied. *Blue* and *red* lines are for GPS and GLONASS satellites, respectively

- The P123 scenario (Figure 6a) is as severe as a 20 degree constant elevation cut-off angle (according to per centage of missing data statistics)

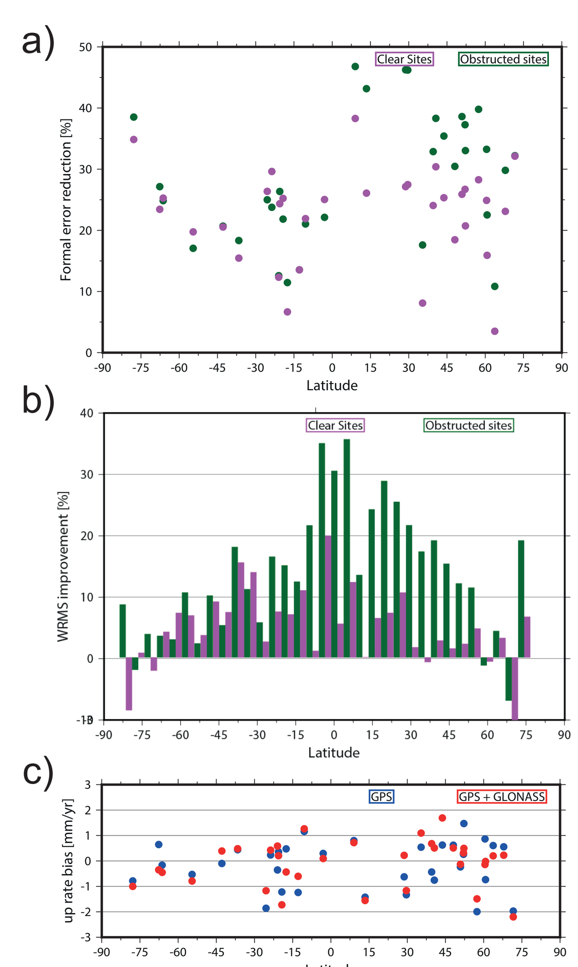


Figure 7 a) Formal error reduction b) WRMS improvement of the combined GPS + GLONASS over the GPS only solutions for the up component. *Magenta* colour for clear sites, *Green* colour for obstructed sites c) Up rate bias due to the P123 scenario for both GPS only (*blue dotes*) and GPS + GLONASS (*red dots*) solutions

► Main Results (for the up component):

- ▫ Effects of the P123 obstruction scenario:
  - − The day-to-day formal errors and WRMS of the time series are larger for the obstructed sites
  - − The rate bias reaches ±1 mm/yr for most of the stations while it is larger than ±1 mm/yr for some (Figure 7c)
- ▫ Benefits of the combined GPS + GLONASS solution:
  - − The day-to-day formal error reductions (Figure 7a) can reach more than 30 % and 40% for clear and obstructed sites, respectively
  - − The repeatability improvement (Figure 7b) reaches 20 % for clear sites and 35 % for obstructed sites
  - − The effect on the estimated rates is not clear and needs further investigation (Figure 7c)

Conclusions:

1. The effect of an obstruction can be of site specific and latitude dependent nature.
2. Obstructing objects cause varying satellite geometry and missing data with features corresponding to the orbit characteristics. They cause bias and noise in GNSS time series and as a consequence bias in the up rate estimations.
3. The combined GPS+GLONASS solution clearly benefits both un-obstructed and obstructed sites with the positive impact being larger for the latter.
4. More work is needed to better quantify the current results and to include observations from Galileo and BeiDou.

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